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Profits in reverse?
An examination of the decisive factors for reverse supply chain profitability

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Abstract

Although the concept of the reverse supply chain (RSC) is not unknown in industry, an inhibitor for its successful use is low (or no) profitability. A research challenge is investigating ways to establish the RSC as a profit-creating center in the organization. This paper contributes to this challenge by examining the factors decisive for whether a firm will achieve profits from operating a RSC. By combining a literature review and multiple case study, the paper identifies a set of factors that prohibit or advance RSC-profitability and develops a set of propositions that define the relation between each factor and RSC-profitability.

Keywords: Reverse supply chain, reverse logistics, original equipment manufacturer

Introduction

While forward supply chains begin with suppliers and end with customers, the reverse supply chain (RSC) begins *and* ends with customers. The prevalent RSC-concept in the theoretical field is formulated by Guide and Van Wassenhove (2002). The concept describes the RSC as a set of five connected processes that begin with acquiring used items from customers, continue with testing, sorting, disassembling and recovering items, and end with resale of recovered items. Figure 1 illustrates the RSC-concept. In this paper internal reuse of recovered items is included in fifth process as an alternative option to remarketing.

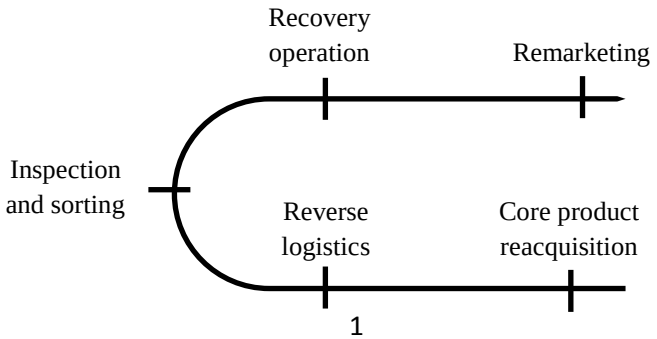

Figure 1 The Reverse Suppy Chain (Guide and Van Wassenhove, 2002)

A recent literature review by Huscroft *et al.* (2012) concludes that one of the greatest needs for scholarly research within the RSC-field is investigating ways to establish the RSC as a profit center in the organization. A report from the Confederation of Danish Industry (DI) supports this research challenge by reporting that one of the greatest barriers for establishing RSCs in the organization is in fact low or no profitability (Tronhus, 2010).

Individual firms can conduct cost-benefit calculations to examine whether implementing a particular set of RSC-processes is profitable for the firm if implemented. Although such calculations give results (positive or negative profitability), it is unknown on a general level which factors are decisive for the outcome of these calculations. To establish the RSC as a profit-creating entity within an organization, managers need a better understanding of what these factors are. The purpose of the paper is to identify the factors, which, if known, are strong indicators to managers about their firm's current RSC-profitability as well as implementation of new RSC-processes. Furthermore, knowing the decisive factors focuses managerial attention on what matters.

To discover the decisive factors the study first identifies the set of factors that influence RSC-profitability directly, which henceforth are labeled "direct influencers". Second, the study examines the sublayers of antecedents to these direct influencers. For example, a direct influencer of RSC-profitability is the cost of disassembling a core product. The disassembly cost depends among others on 1) the disassembly run time per item, 2) the investment in necessary processing technology, and 3) the level of training and worker expertise needed. These three factors depend on the ease of disassembly.

The sum of identified factors (direct influencers and antecedents) form a hierarchy, which shows dependencies and causal relations among factors. Within the sublayers of antecedents lie the root causes of low or no profitability, and it is the purpose of this study to explore exactly what these factors are.

Several papers have examined factors that influence RSC-profitability. For example, the cost of acquiring core products (Guide and Van Wassenhove, 2001), the cost of reverse logistics (e.g. Krikke *et al.*, 2008), the degree of virgin product sale cannibalization (Guide and Li, 2010), and the impact of time on the value of recovered items (Blackburn *et al.*, 2004). However, until now no paper has looked broadly on the overall set of factors. Such an examination can reveal the hierarchy of how factors relate to one-another and it may identify possible factors that are unexplored in extant literature.

Domain limitation

The domain of the study is limited to RSCs of original equipment manufacturers (OEMs) described roughly as in Karlsson (2003) and Geyer and Jackson (2006). The particular type of OEM, which is focal to this study, is a producer of durable products. The OEM conducts assembly and fabrication of *some* components in-house, while remaining components and all materials are sourced. For the remainder of the paper firms fitting this description are referred to as the study's "focal OEM".

The RSC of the focal OEM can perform a variety of different functions for the firm. Two examples of RSC-functions are 1) taking back used products for refurbishing and resale to secondary markets and 2) taking back used products to disassemble, refurbish and reuse components as spare-parts in the firm's servicing of their installed product base. The first example leads to a new stream of revenue, while the second leads to a continuous stream of cost savings by avoiding the costs of producing spare-parts as well

as the costs of purchasing materials. Identification of the factors, which are decisive for RSC-profitability, depends on the nature and number of RSC-functions of a RSC. For this study we select a RSC with a predefined set of RSC-functions. Specifically, the study chooses a set of RSC-functions similar to the set in Larsen and Jacobsen (2014), which makes the set of cost parameters developed in their paper usable in this study. The following three bullets describe the set of RSC-functions of the RSC of the focal OEM in this study:

1. End-product refurbishing for the purpose of resale as low-cost versions of the OEM's virgin product to the firm's primary market
2. Component refurbishing for the purpose of reuse as spare-parts in the firm's service of their installed base of products
3. Sale of core materials upstream to current virgin material suppliers or material recyclers

Figure 2 illustrates the focal OEM's RSC. The figure provides a more elaborate version of the five processes in the RSC-concept by Guide and Van Wassenhove in Figure 1. Beginning from the right in Figure 2, core products are acquired from customers and shipped back to the firm's facility through reverse logistics. Then, products are inspected and sorted for possible recovery. If recovered, products are resold. If products cannot be recovered they are disassembled and individual components are inspected for possible component recovery. Components that can be covered are reused the firm's service operations. Components that cannot be recovered are disassembled into their individual materials. Valuable materials are resold back to their original supplier for recycling while other materials enter the waste stream.

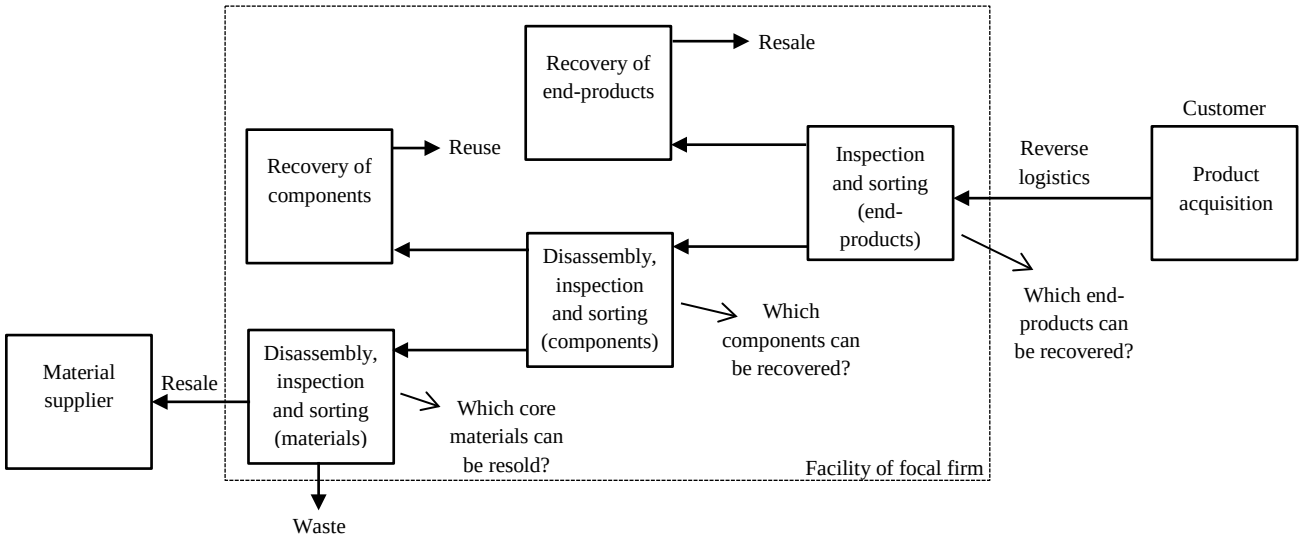

Figure 2 – The RSC of the focal OEM in the study

The remainder of the paper is organized as follows. First, the paper reviews related research to identify direct influencers as well as antecedents already captured in academic writings. Second, the paper delineates the paper's methodology. Third, directly influencing factors and antecedents are identified and a factor hierarchy is formed using extant literature and a multiple case study. Fourth, findings are presented and discussed. Fifth, the paper provides conclusions.

Literature review

The purpose of this section is to review related academic literature to identify factors that influence RSC-profitability. These may take the form of either direct influencers (e.g. disassembly costs) or as antecedents to the direct influencers (e.g. the ease of disassembly). Later in the paper these factors are inserted into the hierarchy of factors.

The literature review is structured roughly around the three themes in Guide and Van Wassenhove (2009): 1) the "front-end" of the RSC about acquiring core products from customers; 2) the "engine", which concerns the OEM's own RSC processes (reverse logistics, sorting, disassembly, and recovery operations); and 3) the "back-end" of the RSC, which concerns remarketing of recovered items.

The "front-end"

Customers play a two-part role in the RSC. They provide the RSC's input (core items) and purchase the RSC's outcomes (recovered items). Several papers describe the task of acquiring core products from the market (e.g. Guide and Jayaraman, 2000; Guide and Van Wassenhove, 2001). The cost of acquiring core items from customers directly impacts RSC-profitability. Products acquisition costs do not include the cost of transport back to the firm, but only the price that the OEM pays the customer for the core product.

Östlin *et al.* (2008) present seven different relationship types between the OEM and the core-owning customer that all allow for core take-back, however at different costs. Independent remanufacturers may compete with the OEM for cores (Ferguson and Toktay, 2006), which ceteris paribus increases the price for cores.

The "engine"

When core products have been acquired, they enter the RSC's "engine". The first step in the engine is reverse logistics, which covers transport, inventory management, and materials handling processes that physically move core products from customers' locations to the OEM's RSC facility. Reverse logistics is well-researched, especially within the OR discipline. Examples are Jayaraman *et al.* (2003), who examine the impact of reverse logistics network design on profitability, and Krikke *et al.* (2008), who investigate collection of materials.

The process of inspecting and sorting cores has not received much attention in literature. For example, the impact of sorting policies on overall RSC-profitability. Van Wassenhove and Zikopoulos examine how quality overestimation affects RSC-profitability negatively, while Robotis *et al.* (2012) examine the effect of inspection capabilities on recovery costs. Hazen *et al.* (2011) present seven components examined in literature that decide whether a product should be recovered. Profits and costs are two of these seven. Galbreth and Blackburn (2006) develop a model specifying the optimal sorting policy for remanufacturing that will minimize the cost of remanufacturing low quality cores. The chosen recovery option for core products has direct impact on the value of the product when recovered. A remanufactured product is more valuable than the sum of components and materials. Theirry *et al.* (1995) provide a list with recovery options.

When products are sorted, those that are sorted for recovery will be disassembled. Tang *et al.* (2004) develop a model supporting the decision of level of disassembly and which components for disassemble for. An optimal solution will reduce the cost of unnecessary disassembly. Williams (2006) reviews disassembly processes within recycling of End-of-life electronics and Das *et al.* (2000) develop a disassembly effort index that supports the decision of whether a product is worth disassembling.

The "back-end"

The value of the recovered product is determined by customers' willingness to pay (WTP). Consumers value remanufactured products lower than virgin products (Debo *et al.*, 2005; Guide and Li, 2010). However, remanufactured products are worth more than refurbished products, because remanufactured products are upgraded to a higher quality level than refurbished products (Thierry *et al.*, 1995). A well-researched area within recovered product remarketing is the effect of cannibalization. Cannibalization of virgin products affects RSC-profitability negatively. Atasu *et al.* (2008 and 2010) examine circumstances where remanufacturing is an effective marketing strategy in spite of cannibalization. The impact of the cycle time a core (and later recovered) product is in the RSC on the value of product is examined by Blackburn *et al.* (2004).

Methodology

The purpose of the study is to identify the direct influencers of RSC-profitability and examine the sublayers of antecedents. The direct influencers are those factors that are explicitly part of cost-benefit analyses that calculate the profitability of a firm's RSC. A direct influencer is either an incoming or outgoing monetary stream. Antecedents are those factors that impact the direct influencers. Figure 3 shows how the three terms are related. The paper will relate direct influencer and antecedent by formulating propositions that explain how an antecedent influences RSC-profitability through the direct influencer.

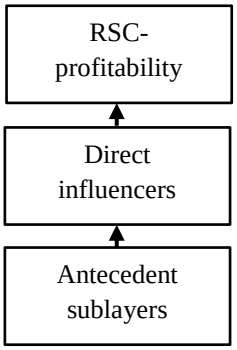

Figure 3 - Simple factor hierarchy

To identify the group of direct influencers the study first looks at the incoming cash flows that the RSC of the focal OEM delivers (either revenue streams or cost savings). These flows are specified in the description of the focal OEM's RSC. Second, the study identifies costs using the concept of the RSC by Guide and Van Wassenhove described in the paper's introduction and the set of cost parameters developed in Larsen and Jacobsen (2014). When in- and outgoing monetary streams are identified, the next step is to examine the sublayers of antecedents. The examination of sublayers of antecedents draws upon two sets of knowledge: 1) the results of the literature review from the previous section and 2) a multiple case study of six firms. The following section describes the case study's purpose and method.

Case study method

The purpose of the multiple case study is to support and extend the formation of a factor hierarchy. While the literature may form the basis for some causal relations between direct influencers and antecedents, the case study will extend the set of relations to include relations not previously captured in academic writings. The study uses three criteria for sampling case firms for the case study:

1. Each firm in the sample must fit the description of the focal OEM (provided previously in the paper)
2. The sum of case firms represent a variety of industries so the sum of firms within the study's population is as well represented as a case study allows
3. The RSC-functions of the case firms' RSCs cover the three RSC-functions in the RSC of the study's focal OEM

Data is collected through interviews, company visits, observations and through the use of written materials (e.g. product descriptions and flow charts). Interviews are the primary data collection technique. Interviews are semi-structured beginning with interviewees describing their firm's RSC processes using open-ended questions. The second part of each interview seeks explanations of the "why". For RSC-functions already in a firm's RSC the interview seeks an explanation of *why*. For potential RSC-functions that are not part of the firm's RSC the interview seeks an explanation for *why not*. Answers to why and why not questions are usually antecedents that impact their RSC's direct influencers. Example: Why does a case firm not recover and resell components. The answer is that all their valuable components are customized heavily for their own firm and are therefore not usable for any other firms, even close competitors.

The table below presents the case firms included in the study as well as each case firm's RSC-functions.

Table 1 - Case firms in study

Case	Industry	RSC-functions
Case A	Industrial measurement equipment	▪ Refurbishing of complete end-products for resale to secondary markets ▪ Refurbishing of components for internal reuse in service processes
Case B	Ship engine equipment	▪ Remanufacturing of end-products for resale to primary and secondary markets ▪ Remanufacturing of components for resale to primary and secondary markets ▪ Resale of core materials to independent recyclers ▪ Take-back and direct resale of non-defect items
Case C	Water distribution equipment	▪ Resale of core materials to independent recyclers
Case D	Hearing aids	▪ Refurbishing of end-products for reuse in "swap with defect product" service ▪ Take-back and direct resale of unused items
Case E	Electronic audio equipment	▪ Refurbishing of end-products for reuse in "swap with defect product" service ▪ Take-back and resale of core materials to independent recycler
Case F	Medical equipment	▪ Refurbishing of complete end-products for resale to secondary markets ▪ Refurbishing of components for internal reuse in service processes

Findings

This section first identifies the direct influencers of RSC-profitability; second, the antecedents; and third, the section illustrates the hierarchy of how factors relate to one-another.

Direct influencers

The direct influencers consist of in- and outgoing monetary streams. There are three ingoing streams resulting from the three RSC-functions in the RSC of the focal OEM. The firm achieves 1) new revenue from resale of recovered products; 2) a continuous cost saving from reusing recovered components, which replaces the cost of internal component production as well as purchasing materials; and 3) new revenue from reselling core materials upstream. The costs are defined through two sources: 1) the five processes in Guide and Van Wassenhove's RSC concept, and 2) the set of RSC-costs developed in Larsen and Jacobsen paper (2014).

The number of different cost parameters included in Larsen and Jacobsen (2014) is large and very detailed. For simplicity and to focus on the larger cost types we omit taking into account cost parameters concerning materials handling, costs of monetary transaction flows, and any type of cost resulting from Larsen and Jacobsen's case firms, which all have a local sales firm and central factory setup. These cost parameters did not play a major role with any of the case firms in this study. Also, all cost parameters concerning the disassembly, cleaning, rework, and testing and grouped under the headline recovery operations.

Antecedents and the hierarchy of factors

The core of this section is Figure 4, which illustrates how antecedents identified either through the literature review or the case study impact the direct influencers. The five black squares represent the five processes in Guide and Van Wassenhove's RSC concept. An additional factor, the value of recovered items, has been identified. Antecedents are numbered consecutively from 1 to 17 (listed in parentheses). How each antecedent impacts RSC-profitability is elaborated in the following section, where the proposition that defines each relationship is described.

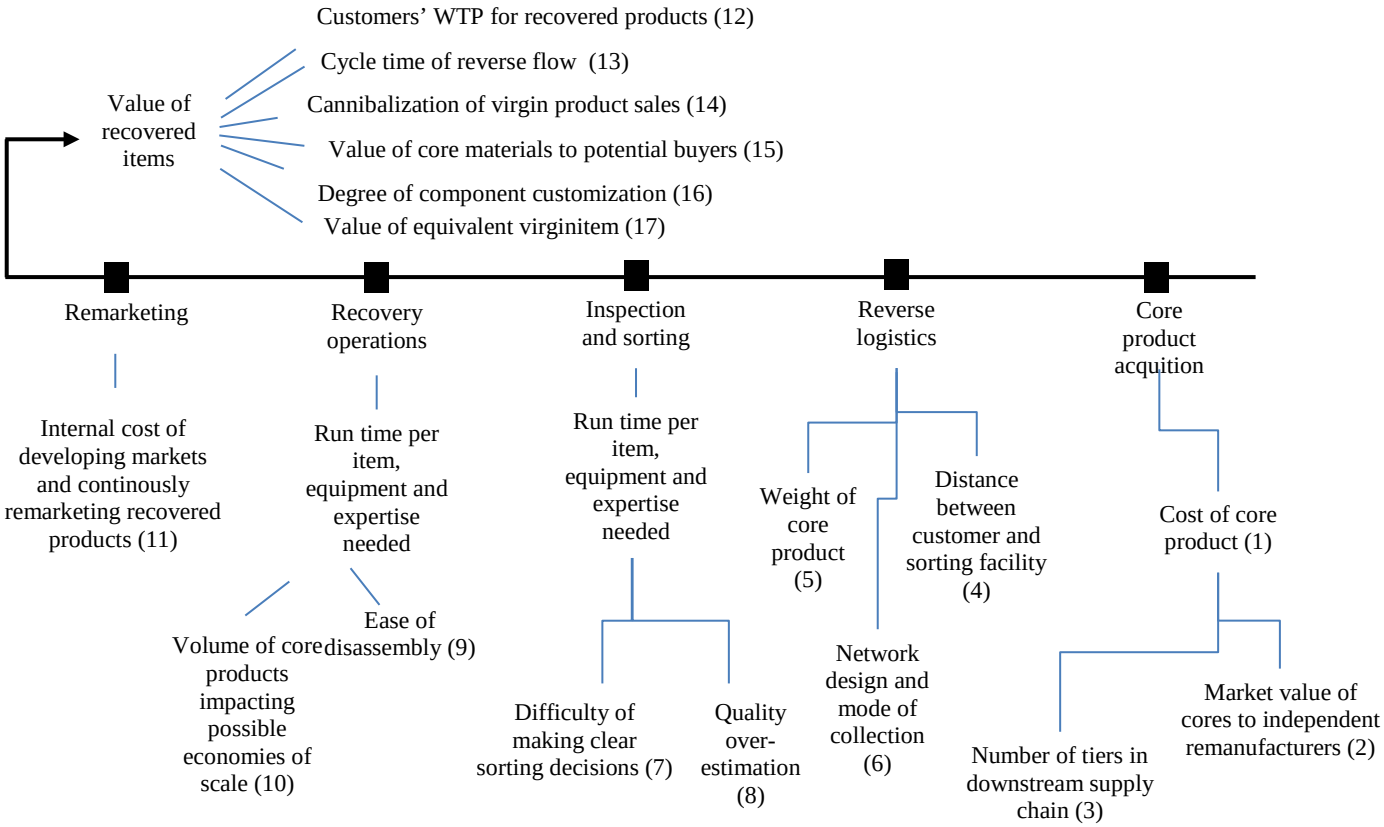

Figure 4 Factor hierarchy of direct influencers and antecedents

RSC-profitability and antecedent relationships

This section presents the set of propositions that relate antecedents to RSC-profitability through the direct influencers. The set of propositions are identified through the use of the literature review, the multiple case study, or both. It may, however, be that a proposition is not identified through either, then the proposition is deduced by the authors of this paper as a suggestion for further research.

Table 2 - Propositions

No.	Proposition	Litera-ture	Case study
1	The type of relationsship between OEM and customer impacts the cost of acquiring core products	**X**	
2	I high market value of a core product to an independent remanufacturer impacts the RSC-profitability negatively by increasing the OEM's product acquisition costs	**X**	
3	I high number of tiers on the OEM's downstream supply chain impacts the RSC-profitability negatively by increasing the OEM's product acquisition costs		**X**
4	The distance between customer and sorting facility impacts profit of RSC through in- or decreasing reverse logistics costs		**X**
5	The weight of core products impacts profit of RSC negatively because of reverse logistics costs		**X**
6	The design of the reverse logistics network and mode of collecting core products impacts RSC-profitability by in- or decreasing reverse logistics costs	**X**	
7	A high degree of difficulty of making the sorting decision increases the costs of run time per item and the level of equipment and skills needed, which impacts the RSC-profitability negatively		
8	Overestimating quality has a negative effect on RSC-profitability by increasing unnecessary recovery operations costs	**X**	
9	The ease of disassembly impacts RSC-profitability by affecting the costs of the recovery operation		
10	A low volume of cores available increases the costs of reverse logistics, inspection, sorting, and recovery and therefore impacts the RSC-profitability negatively		**X**
11	The internal cost of developing markets for recovered items and the continuous effort of remarketing impacts RSC-profitability negatively		
12	A high customer WTP for recovered items impacts the RSC-profitability positively	**X**	
13	The time a core (and later recovered item) spends in the reverse supply chain impacts RSC-profitability by affecting the value of the recovered item when remarketed	**X**	
14	A high degree of virgin product cannibalization impacts RSC-profitability negatively	**X**	
15	The value of core materials impacts RSC-profitability because extraction of materials requires the full breath of potentially costly disassembly		**X**
16	A high degree of customization and low reconfigurability of components decreases the value of a recovered component because the amount of potential buyers is lower		**X**
17	Low value of individual products impacts the profits negatively because the potential for cost reductions achievable through replacing virgin products with recovered products is low		**X**

Discussion

While the literature focuses much on cannibalization, customer WTP and reverse logistics network design, the firms in the case study focus on other issues, e.g. weight and distance of core products, degree of customization, and number of tiers in the downstream supply chain. So, many of the factors that impact RSC-profitability in OEMs that fit the description of the “focal OEM” have not been examined in academia.

Conclusions and suggestions for further research

The set of decisive factors in Figure 4 and the set of propositions that explain how each factor prohibits or advances RSC-profitability provided in Table 2 gives managers and scholars a better understanding of RSC-profitably. Using the set of identified factors

managers are better able to influence their profitability of their RSC. They might e.g. 1) ease disassembly processes through advanced technology or product design changes, 2) lower products' weight through lighter materials, or 3) develop markets with higher willingness-to-pay for recovered items.

Future research opportunities

The paper's results offer ample opportunities for future research. The paper has proposed a set of testable propositions, that each propose how an antecedent to a directly influencing factor of RSC-profitability is related. While some propositions are based on literature, others are based on the multiple case study of this paper and deductions from the authors themselves. Each of those factors deserves examinations.

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